(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 710 515 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
08.05.1996 Bulletin 1996/19

(51) Int. Cl.^{6}: B21K 1/00, B21K 1/38

(21) Application number: 95830240.8

(22) Date of filing: 08.06.1995

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IE IT LI LU NL PT SE

(30) Priority: 07.11.1994 IT BO940484

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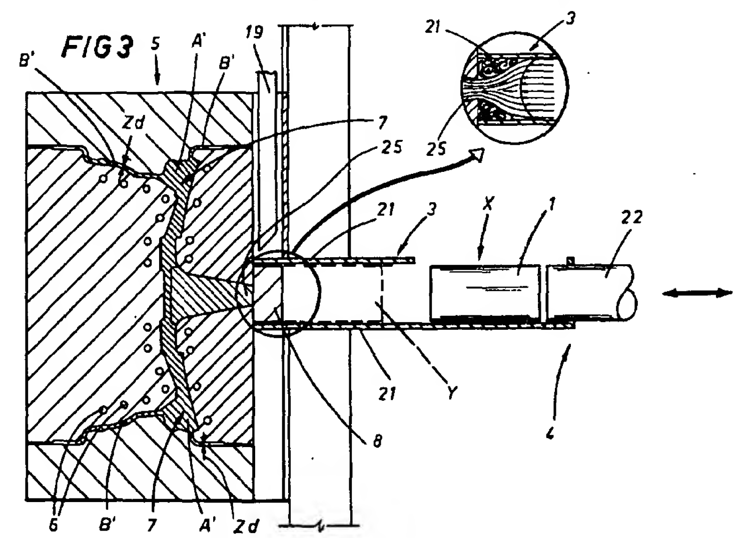
(54) Thixotropic forming process for wheels fashioned in rheocast metal alloy

(57) The starting material in a thixotropic forming process for the manufacture of road wheels, fitted ultimately with pneumatic tyres, is an ingot (1) of rheocast metal alloy preheated to the semisolid state: the ingot is injected into a closed die (5) affording a cavity (7) in the shape of the wheel and equipped with independent thermoregulating circuits (6), routed and controlled in such a way as to maintain the wider passages (A) of the cavity at a temperature lower than that of the narrower passages (B); to ensure the die fills properly, the ingot (1) is injected at a variable and controlled velocity, correlated both to the rate at which the alloy spreads through the cavity (7) and to the geometry of the cavity itself, whereupon a pressure much higher than the injection force is applied to the solid-semisolid interface within the alloy, and sustained until full solidification is achieved.

FIG 3



Printed by Rank Xerox (UK) Business Services
2.11.3/3.4

Description

The present invention relates to a thixotropic forming process suitable for wheels fashioned from rheocast metal alloy in the semisolid state, and in particular for the manufacture of aluminium alloy road wheels fitted ultimately with pneumatic tyres.

The shaping processes employed conventionally in the manufacture of road wheels for pneumatic tyres are essentially those of forging, and casting in permanent moulds, both of which well known in the wider field of mechanical engineering.

Forging is the familiar process by which a metal alloy can be shaped in the solid state. Employed in the particular context of the art field pertinent to the manufacture of wheels for pneumatic tyres, this is a facility which allows the realization of products with superior mechanical properties, but which at the same time gives rise to a number of drawbacks, namely, the need to use alloys suitable for plastic working, the impossibility of producing articles with geometrically complex shapes, and the fact that the end product will be arrived at only after implementing a series of consecutive steps, especially a product characterized by significant variations in thickness such as are evident in the typical geometry of a road wheel. The high cost of the forging process represents a further drawback.

The process of casting in a permanent mould, where an alloy is worked in the liquid state, allows the realization of a product at low cost in relatively few steps, and in this instance even with complex geometries. By contrast, the mechanical quality of the cast product is inferior to that of the forged product, and, moreover, with casting no less than with forging, there is the need to utilize alloys having particular intrinsic properties specifically suited to the technological process in question.

More especially, the lower mechanical quality of the cast wheel is attributable to the structural characteristics of casting alloys, as well as to the porosity and discontinuity which are generated within the fabric of the wheel and derive from the particular type of casting process.

In addition, both of the processes mentioned above are characterized in that the forged or cast piece requires generous allowances of material, dictating the need for extensive additional machining steps before the piece can be considered an end product.

Recent times have seen the development of a new technology, namely the thixotropic forming of metal alloys in the semisolid or semiliquid stated; in this instance, the end product is obtained from an ingot or billet exhibiting a particular structure that appears physically homogeneous on macroscopic inspection, but when viewed microscopically appears as a plurality of solid globular granules immersed in a liquid phase. The ingot can take on different characteristics according to the percentages, by weight, of the solid and liquid fractions: in the case of a semisolid, the material can behave in the manner of a solid, for example when conveyed from a heating station to a work station or thixotropic injection forming station, but in the manner of a liquid when injected under pressure.

There are currently no known applications of this new technology in the art field that embraces the manufacture of wheels for pneumatic tyres.

Given that there are clear advantages and drawbacks alike with both the forging process and the casting process conventionally adopted in the manufacture of road wheels, as intimated above, the object of the present invention is to overcome the drawbacks of each such method while combining the advantages.

The stated object is realized, according to the present invention, in a thixotropic forming process by means of which to fashion wheels for pneumatic tyres, using rheocast metal alloy, as characterized in the appended claims.

To particular advantage, the process disclosed can be applied in manufacturing metal alloy wheels even of complex geometry, including slender sections and much broader sections alternating substantially in unlimited manner, and thus incorporates a feature characteristic of the permanent mould type casting techniques mentioned above.

The invention will now be described in detail, by way of example, with the aid of the accompanying drawings, in which:

- figs 1, 1a, 1b and 1c schematically illustrate the succession of steps making up a complete cycle in the manufacture of wheels for pneumatic tyres utilizing the thixotropic forming process according to the present invention;
- fig 2 is the schematic illustration of a machine designed to implement the process according to the invention, viewed in plan;
- fig 3 illustrates the machine of fig 2 partly in section through III-III, seen with certain parts omitted better to reveal others;
- fig 4 illustrates a detail of fig 3 relative to the injection step of the process according to the invention.

With reference to the accompanying drawings, the invention relates to a process for the manufacture of wheels in rheocast metal alloy, typically road wheels fitted subsequently with pneumatic tyres, which utilizes billets of rheocast aluminium alloy obtained in conventional manner by recasting from pigs of raw stock having a dendritic structure. The liquid alloy is directed through a filter and into a casting device equipped with an agitator and a chill, whereupon the cooling material solidifies and is formed into billets exhibiting a rheocast microstructure. The billets are then divided into ingots 1 of predetermined weight, which undergo controlled heating at a temperature within the solidification range of the alloy and are brought to a thixotropic semisolid state characterized by a microstructure (indicated in fig 1a) that comprises a liquid phase 14, resulting from the components of the alloy having a lower melting point, and a mass of

substantially rounded solid granules 15 immersed in the liquid.

The ingots 1 are uplifted in this same semisolid state, for example by automatic handling means 23 (as indicated in fig 2) and introduced singly into the injection chamber 3 of a thixotropic injection forming machine 4 (figs 1, 2 and 3) operating in conjunction with a closed die or mould 5 by which the wheel 2 is effectively given its shape.

As discernible in figs 1 and 3, the die 5 affords a cavity 7 of shape substantially matching that of the wheel 2 and is provided with thermoregulating circuits 6 carrying a hot fluid, oil for example, supplied by a unit not shown in the drawings. The injection chamber accommodates a ram 22 that can be reciprocated at a variable rate by the thixotropic injection forming machine 4 (described more fully in due course).

The thermoregulating circuits 6, which run adjacent to the die cavity 7, are mutually independent and arranged in such a way that sections A' of greater width exhibited by the cavity 7 can be cooled, or more exactly heated to a lower temperature, whilst sections B' of lesser width are heated to higher temperature. The term "width" is used to indicate the transverse dimensions of the space afforded by the relative passage of the cavity 7.

The features in question are intended to ensure the die 5 is filled completely and uniformly, as will emerge from the specification in due course.

Given the typically variable geometry of wheels for pneumatic tyres, and given the alternation between sections B of lesser thickness and sections A of greater and accentuated thickness, the operation of filling the die 5 with the alloy in its semisolid state is a particularly critical one. A complete fill is in fact made possible only by ensuring that the liquid phase of the semisolid alloy (which in any event is proportionally less than the solid) does not solidify within the sections B' of lesser width and thus block the passage afforded to the semisolid material entering the cavity 7, forced in by the ram 22, before the part of the die 5 beyond the blockage has been filled to capacity. In other words, it is essential that the interface between the solidifying alloy and the liquid phase of the injected semisolid mass should progress regularly, advancing internally of the die cavity 7 from the peripheral parts of the wheel 2 back to the areas nearer the injection chamber 3.

In accordance with the present invention, wheels for pneumatic tyres are manufactured from rheocast metal alloy employing a thixotropic forming process in which use is made of ingots 1 already preheated to the point of bringing the alloy to the uniform semisolid state described above.

Before describing the process further, it should be remarked that the aforesaid sections A of greater thickness exhibited by the typical wheel 2 consist in a central disc 9 incorporating a hub 9a, and a plurality of spoke ribs 10 radiating from the hub in alternation with respective voids 11. The same wheel also presents sections B of lesser thickness consisting in a lateral cylindrical surface 12 or rim composed of an inner portion 13 and an outer portion 16. The two portions are compassed in turn by an inside flange 17 and an outside flange 18.

The process comprises a step of injecting the metal alloy ingot 1, in the semisolid thixotropic state, into the cavity 7 of the die 5.

In a die designed to produce a first embodiment of the wheel 2, as illustrated in figs 1 and 1c, the width Zi at least of the narrower section B' of the cavity 7, which corresponds to the inner portion 13 of the rim 12, is greater than the width Zd that will determine the definitive or final shape of the inner portion 13. Accordingly, the thickness Si of this same portion 13 on completion of the injection step will be greater than the final thickness Sd to be obtained on completion of the process overall.

During the injection step of the process, a step of thermoregulating the die 5 is implemented by way of the relative circuits 6 which, to reiterate, are able to maintain a relatively higher temperature in the cavity 7 at the sections B' of lesser width and at the same time a relatively lower temperature at the sections A' of greater width.

Likewise during the injection step, the velocity at which the ingot 1 is forced into the die will be monitored and varied by monitoring and varying the linear velocity of the ram 22, and thus controlling the rate at which the front of metal alloy advances in the semisolid state internally of the cavity 7.

The injection rate is a function of the dissimilar flow passages afforded by the wider and narrower sections A' and B' of the cavity 7, and continues to be controlled until the die has filled, thereby allowing a faster advance of the front of semisolid alloy through the wider areas A' of the cavity 7 and a slower advance through the narrower areas B'.

Accordingly, the movement of the thixotropic alloy internally of the cavity 7 is made laminar as far as possible.

In order to optimize the compaction of the metal alloy within the cavity 7 following the injection step and during solidification, the material is subjected to an additional pressure force, applied through the ram 22 by the thixotropic injection forming machine 4, compounding and therefore much greater than the injection pressure force applied previously. Solidification is followed by the steps of removing the wheel 2 from the die 5 and then hot-drawing the inner portion 13 of the rim 12 by compression. The purpose of the drawing operation is to reduce the inner portion 13 from the initial injection forming thickness Si, indicated in fig 1c by phantom lines, down to the definitive or final thickness Sd. Moreover, this step has the effect of achieving increased mechanical strength, at least across the inner portion 13 of the rim 12, and of compacting the metal alloy still further so as to avoid the eventuality, should the finishing steps of manufacture involve the removal of material by machining, that interstices could then appear in the structure and jeopardize the airtightness of the whe l when fitted ultimately with a pneumatic tyre.

In another solution illustrated in figs 1 and 1b; both of the narrow sections B' exhibited by the die cavity 7, which generate the lateral surface 12 of the wheel 2, are proportioned to a width Zi greater than the definitive or final width Zd, as described already with reference to fig 1c. With the wheel 2 removed from the die in this instance, therefore, it is the entire lateral surface 12 that will be hot-drawn by compression to the end of reducing the initial thickness Si to the definitive or final thickness Sd, as in the previous example.

In a further solution illustrated in fig 3, the selfsame thixotropic forming process is implemented using a closed die 5 with a cavity 7 of geometry, sectional profile and dimensions identical to the final geometry, sectional profile and dimensions of the wheel 2. In this instance, no drawing operation is performed on the wheel 2 once removed from the die 5.

With regard to the step of preheating the alloy, the process allows for the application of a heat treatment whereby the ingots 1, initially in the solid state, are immersed in convectional flows of hot air for a period of time and at a temperature sufficient to bring the alloy to the thixotropic semisolid state.

For the reasons mentioned previously, the step of injecting the semisolid ingots 1 is implemented generally at low velocity so that laminar flow can be induced in the thixotropic alloy; in addition, the velocity is varied cyclically so as to ensure a uniform progression of the solidification interface aforementioned.

As discernible from fig 3, the ingot 1 is advanced by the ram 22 of the injection forming machine 4 from a first position X of introduction into the injection chamber 3, to a second position Y from which the material is forced into the die 5. In passing from position X to position Y, the ingot 1 is forced at minimal velocity so that air will not be trapped between the ingot 1 and the wall 21 of the chamber 3 and allowed thus to find its way into the die cavity 7 at the next injection.

Solidification of the liquid phase in the semisolid alloy represents a critical aspect of the process disclosed, as already explained. Nonetheless, as long the rheocast alloy introduced into the die cavity 7 has a solid content of some 50 or 60%, this ensures advantageously that contractions and thermal shocks will be of a limited order.

As stated at the outset, the ingots 1 utilized are of a predetermined weight. More exactly, the weight of the ingot is selected to ensure a quantity of the alloy greater than can be contained within the die cavity 7, so that on completion of the step in which the ingot 1 is injected into the cavity 7, a residual portion 8 of semisolid material is left to solidify externally of the die 5, between the die and the injection chamber 3 (see fig 3).

This deliberately generated residual portion 8 of the ingot is instrumental in achieving homogeneity and quality of the wheel. More exactly, the inlet of the die 5 presents a restricted section 25 to the ingot 1 passing from the injection chamber 3 to the cavity 7, of which the effect is to gather up the skin 20 of the ingot, physically and chemically distressed by the intense oxidizing action of the air especially on the liquid phase of the rheocast material, when forced from the injection chamber 3 (see fig 4).

Following the injection and solidification of the alloy, the residual portion 8 of the ingot 1 must be cut off, and accordingly, the process includes a shearing step effected by a blade 19, which will be operated after the injection chamber 3 is distanced from the die 5.

A wheel of the type described above can be obtained substantially in a single operation, and, unlike other comparable cast alloy road wheels, betrays no problems of porosity thanks to the viscosity of the semisolid alloy, the variable rate of injection and the advantages of the subsequent hot-drawing step; the wheel described and illustrated also benefits from closer dimensional tolerances due to the fact that solid contractions, affecting only the liquid fraction of the semisolid alloy, are compensated by the application of high pressure forces within the solid-liquid interface, with the result that fewer machining operations are required. In addition, the process disclosed might comprise the further step of heat treating the wheel 2 after its removal from the die 5, and after the step of hot-drawing the rim 12 by compression, if included. This would be a heat treatment designed to induce solid solution in the thixotropic metal alloy from which the wheel is fashioned.

Following heat treatment, the wheel 2 will be age hardened to the end of preventing precipitation in the alloy. Thereafter, the wheel can be machined to remove surface material from the rim 12, and more exactly, to remove the machining allowance left by the earlier compression hot-drawing step performed on the inner portion 13, and possibly on the outer portion 16, of the lateral surface 12.

A wheel produced by the process according to the present invention possesses the premium mechanical properties typical of the forged product, and is also superior in quality to the cast product, thus further improving the resistance to fatigue and the tenacity of the alloy road wheel, and enhancing its appearance.

A further characteristic of any wheel obtained by means of the process disclosed is the especially homogeneous structure of the material from which the wheel itself is fashioned.

Claims

1. A thixotropic forming process for wheels fashioned in rheocast metal alloy and fitted with pneumatic tyres, utilizing ingots (1) subjected initially to a preheating step in order to bring the globular metallic microstructure of the rheocast alloy to a semisolid state, uniform throughout the ingot (1), and generating wheels (2) typically with sections of greater thickness (A) consisting in a disc (9), and radiating from the disc, a plurality of spoke ribs (10) alternated with respective voids (11), also sections of lesser thickness (B) consisting in a substantially cylindrical lat-

eral surface (12) or rim appearing as an inner portion (13) and an outer portion (16) compassed by an inside flange (17) and an outside flange (18), characterized in that it comprises the steps of:

- injecting the metal alloy ingot (1), while in the semisolid thixotropic state, into a closed die (5) of which the cavity (7) bearing the shape of the wheel (2) presents sections of greater width (A') corresponding to the sections of greater thickness (A) exhibited by the wheel (2), and sections of lesser width (B') corresponding to the sections of lesser thickness (B) exhibited by the wheel (2), proportioned such that the width (Zi) at least of the section of lesser width (B') corresponding to the inner portion (13) of the lateral surface (12) is greater than the width (Zd) that will establish the definitive or final thickness of the selfsame inner portion (13);
- thermoregulating the die (5) by maintaining a relatively higher temperature at the sections of lesser width (B') exhibited by the cavity (7) and at the same time a relatively lower temperature at the sections of greater width (A') exhibited by the cavity (7);
- simultaneously monitoring and varying the velocity at which the ingot (1) is injected, in such a way as to effect and control a variation of the rate at which the front of metal alloy in the semisolid state advances within the cavity (7) through the dissimilar flow passages afforded by the sections of greater width (A') and the sections of lesser width (B'), until the cavity is completely filled, and in such a way that the semisolid front advances at a faster rate through the sections of greater width (A');
- thereafter, subjecting the metal alloy solidifying internally of the cavity (7) to a pressure force greater than the injection pressure force, thereby achieving greater compaction of the material within the die;
- removing the formed wheel (2) from the die (5), and proceeding to hot-draw the inner portion (13) of the lateral surface (12) by compression, thereby reducing the initial thickness (Si) of the selfsame inner portion (13) down to a definitive or final thickness (Sd).

2. A process as in claim 1, wherein the ingot (1) is of volume and mass greater than the volume and mass of the quantity of alloy that can be accommodated within the die cavity (7), so that the injection step terminates before the entire mass of the ingot can enter the cavity, and a residual portion (8) containing the skin (20) of the ingot (1), gathered and retained internally of a chamber (3) from which the material is injected, is left to solidify in an intermediate position between the inlet (25) of the die (5) and the injection chamber (3), whereupon the solidified residual portion (8) is cut off in a further step of the process effected prior to the step of removing the formed wheel from the cavity (7) of the die (5).

3. A process as in claim 1, utilizing a closed die (5) of which the cavity (7) is proportioned such that the width (Zi) of the sections of lesser width (B') corresponding to the lateral surface (12) of the wheel (2) is greater than the width (Zd) that will establish the definitive or final thickness of both the inner portion (13) and the outer portion (16) of the selfsame lateral surface (12), wherein the step of removing the formed wheel (2) from the die is followed by the step of hot-drawing the lateral surface (12) by compression in such a way that the inner portion (13) and the outer portion (16) are reduced from their initial thickness (Si) down to the respective definitive or final thickness (Sd).

4. A process as in claim 1, wherein the ingot (1) is injected into a die (5) of which the cavity (7) exhibits geometry, sectional profile and dimensions identical to the definitive geometry, sectional profile and dimensions of the wheel (2), thereby dispensing with the step of hot-drawing the lateral surface (12) by compression.

5. A process as in claim 1, wherein the step of thermo regulating the die (5) is implemented by means of a heating fluid circulated within a plurality of mutually independent thermoregulating circuits (6) disposed peripherally in relation both to the die cavity (7) and to an injection chamber (3) from which the ingots (1) are forced into the cavity.

6. A process as in claim 1, wherein the preheating step consists in a heat treatment whereby metal alloy ingots (1) in the solid state are exposed to convectional flows of hot air for a period of time and at a temperature sufficient to bring the alloy to the thixotropic semisolid state.

7. A process as in claim 1, wherein the thixotropic metal alloy ingots (1) are composed, when in the semisolid state, of a solid phase proportioned to constitute between 50 and 60% and a liquid phase proportioned to constitute the remaining 50 to 40%.

8. A process as in claim 1, wherein the step of hot drawing at least the inner portion (13) of the lateral surface (12) by compression is followed by a step of heat treating the wheel (2) to the end of inducing a solid solution in the thixotropic alloy.

9. A process as in claim 8, wherein the solution heat treatment step is followed by a hardening step.

10. A process as in claim 8 or 9, wherein the step of hot drawing at least the inner portion (13) of the lateral

surface (12) is followed by a machining step serving to eliminate the removable allowance left in the previous forming steps of the process.

11. A wheel for pneumatic tyres fashioned from rheocast metal alloy, characterized in that it is obtained by way of the process as recited in claims 1 to 10.

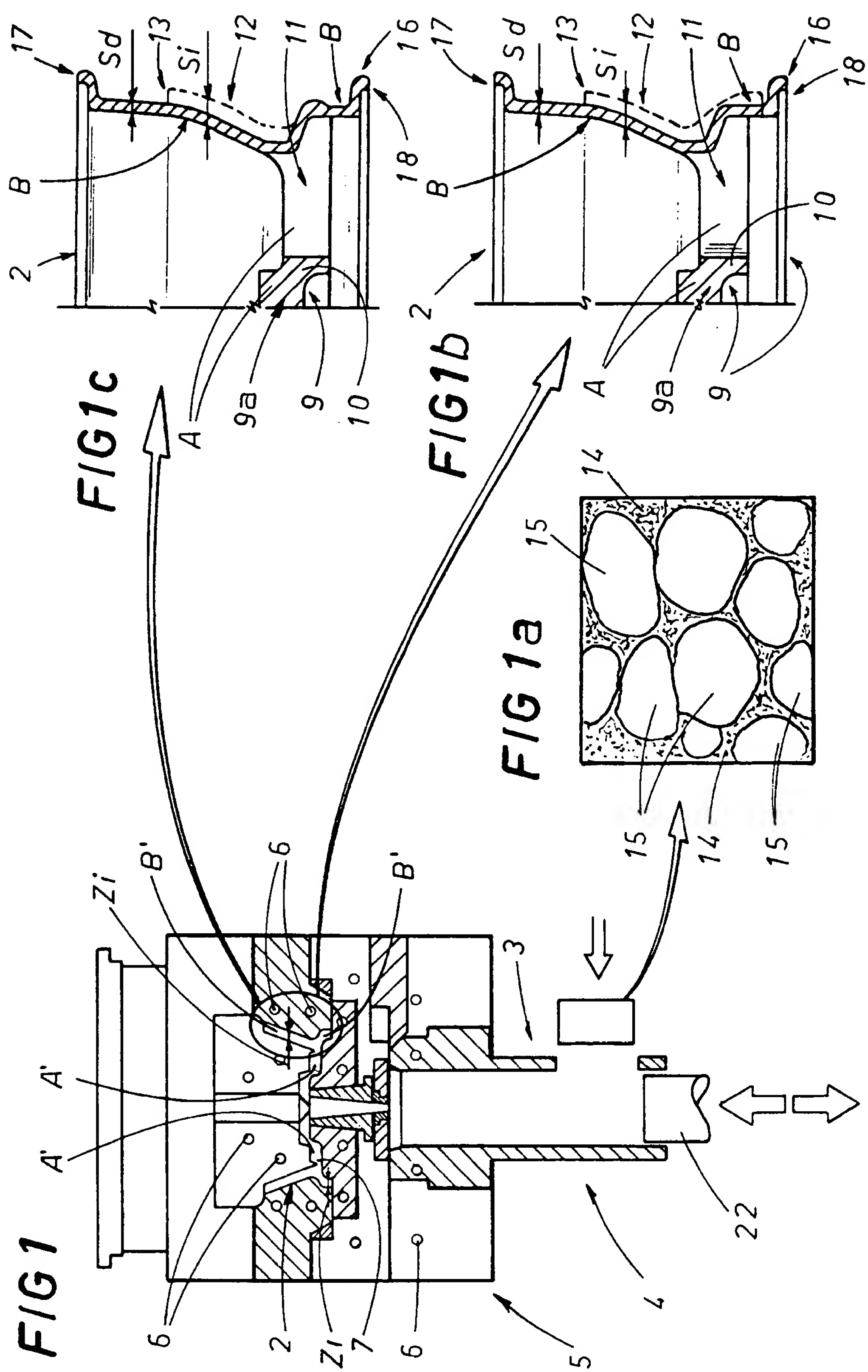


FIG1
FIG1a
FIG1b
FIG1c
A'
B'
Zi
Sd
Si
A
B
9a
2
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6
7
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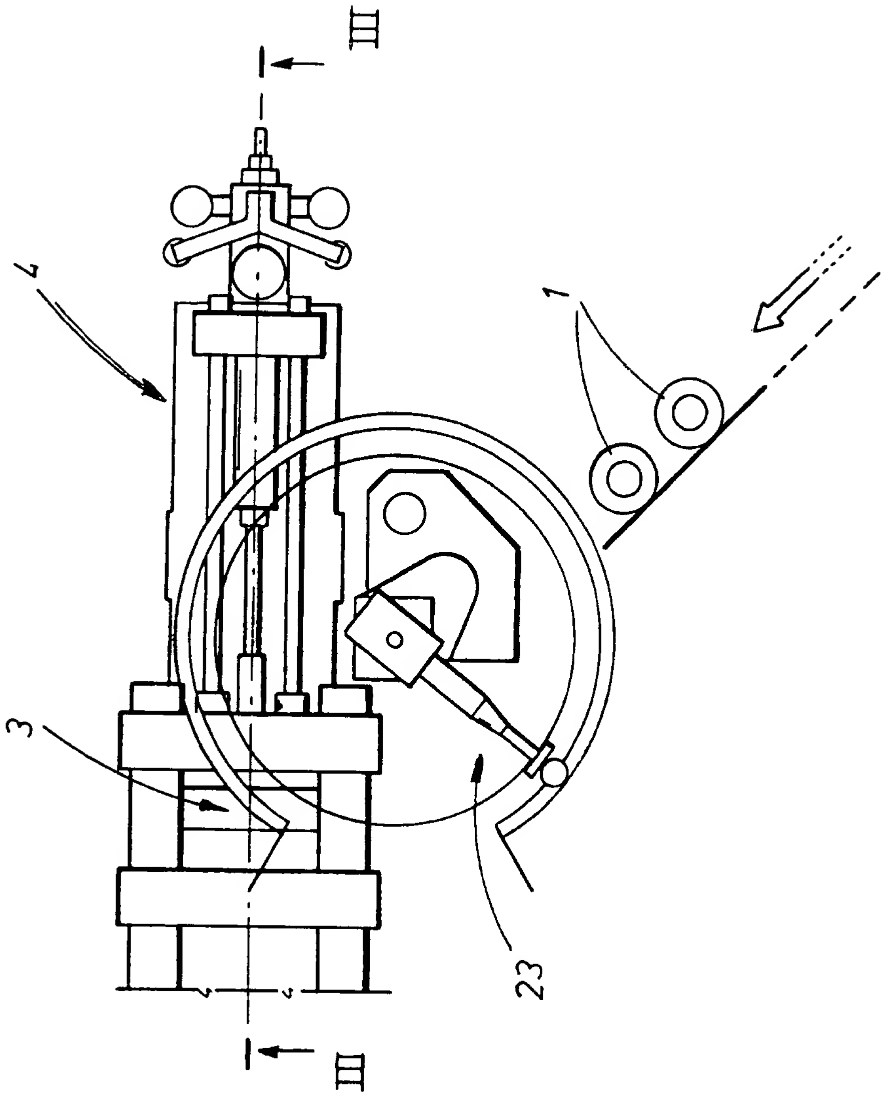

FIG 2

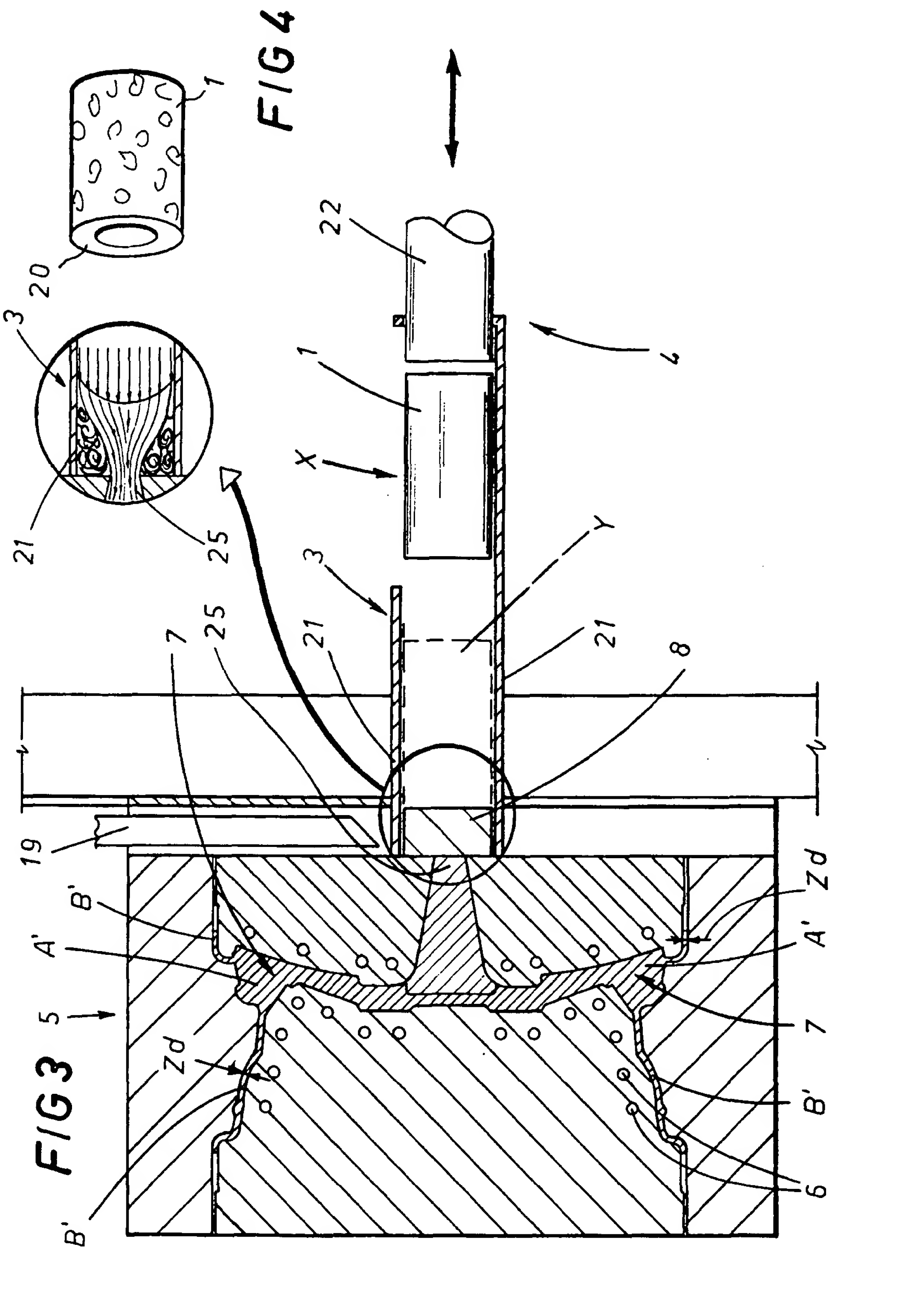

FIG 3

FIG 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 83 0240

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	GB-A-2 026 363 (ITT INDUSTRIES INC) * page 2, line 10 - line 34 * * page 3, line 16 - line 61; figures *	1,4,7,11	B21K1/00 B21K1/38
A	EP-A-0 489 503 (MICROMATIC OPERATIONS INC) * column 12, line 44 - column 13, line 3; figures *	1,2	
A	EP-A-0 379 453 (ALUMINIUM PECHINEY) * column 6, line 32 - column 7, line 56; figures *	1,2	
A	US-A-4 579 604 (BEYER) * column 3, line 31 - column 6, line 11; figures *	3,8-10	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
B21K
B22D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14 February 1996	Barrow, J

CATEGORY OF CITED DOCUMENTS

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